Mini Review

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Roots, the hidden tree

Abstract

In order to adapt the forces a forestry machine to the ground conditions and avoid rutting, ground and tree damages, we must know more about the strength of roots, since they are important factors for the strength of the forest floor. Also tree root bark strength is important to avoid root damages which may cause rot infections in the tree.

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Root strength

Facts

Increased mechanisation of forest work leads to more intensive traffic in the stand.[1] Wheeled or tracked contacts exerts forces from the vehicle down to the contact with the ground, both normal forces (weight) and shear forces (traction). It is estimated that the ground strength is depending both on the soil type but to 40-60 % on the root and rhizomes strength (rhizomes = underground stem and roots of some shrubs, like blueberries (Vaccinium myrtillus) and heather (Calluna vulgaris)). However, data on the strength of the underground woody part is missing.[2,3]

Systematic root studies were started in the eighteenth century. With a simple excavation technique[4] drug out root systems of cultivated crops and determined their morphology, as well as weight and length,[5] tree root systems. Then for over hundred years no important root research was documented Böhm.[6] However, he missed the Swedish studies by Björkhem[7] which had done both root excavation and soil strength testing and they used the monolith method (Figure 1).

Figure 1 Deep rutting in the wet humified soil and lots of roots are cut off after a thinning operation.

Stumps and roots have similar types of wood cells as the stems but they are thinner and shorter than in the stem. Hakkila[8] compiled the literature around the world and came to the conclusion that a. 22 % of the biomass in a tree is below ground (including the stump). Hakkila (op cit.) also noted that a. 18 % of the total root mass was less than 5 mm. At good conditions the cells have bigger lumen and are less lignified than at poorer sites, to be able to transport both water and nutrients to the top; Wästerlund and some forestry students, 1993 (Figure 2).

The shear strength for some tree stem wood species can be found Bodig & Jayne,and for lodgepole pine it is 724 psi (4.99 MPa) and for Sitka spruce it is461 psi (3.18 MPa). When modelling strength properties of wood components, it is usually to just calculate the cross-section area. According to Hooks law, the normal stress is:

$$F / A = kl / A \; \sigma = kl / A \; \gamma$$

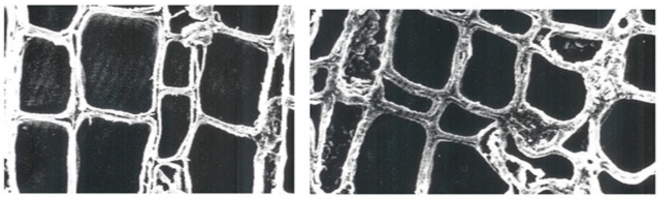

Figure 2 Spruce roots to the left on a rich site and to the right on a poor site.

which is also called Young`s modulus, where k value (spring constant) must be determined experimentally for each material and (l) is the length of the sample and y is normal strain, dimensionless. The force (F) is linear regardless of form (A), the main thing is to have control of cross-section are. Thus, for roots the main factor is actually to have control of the cross-section areas, because it is difficult to keep track on what root and diameter that gives the major strength in a foot print.

The normal pressure behind a wheel is most often higher compared to the longitudinal stresses in the elastic-brittle humus layer,[9] which means the roots are subjected to stretching force since the roots are attached to the soil further away with their branching.

Measurements

This means that tensile strength and elongation of roots are very important including the strength of bark. The strength of the roots and rhizomes were measured with a Hounsfield tensile tester (Figure 3) with the ends of the root samples wired with soft sandpaper to get a good grip. About 100 – 50 mm long and rather straight samples were selected for testing (Table 1). The samples were cut out from the humus layer and stored the short time between field and laboratory in plastic bags to avoid drying out. The tests were conducted with a rate of 50-75 mm/min. Root strength increases with diameter after a. 2-2.5 mm diameter when the lignifying process have started for trees. The elongation during each tensile test was measured with a clamp near the grip holder and an extensometer connected between the holders to give the elongation in mm and then calculated in % based on the free length of the sample between the holders. The strength was calculated based on the cross section of the area at were the root broke. For trees the strength increased with increasing diameter and age of trees.

Table 1 Compilation of root tensile strength data

	Diameter, mm under bark	Strength N /mm², MPa	Extension %	No of samples
Pine, Pinus sylvestris				
In the stand				
12-years old	1.9 – 6.2	32,95	8.74	18
26 years old	1.8 - 3.5	17.17	16.94	9
143 years old	2.0 – 2.9	12.32	8.7	10
W. avege	2.0 – 6.8	27.65	8.79	8
		24.22	10.38	
Spruce, Picea abies				
Forest soil				
Agricultural soil	1.4 – 5.1	38.92	27.87	12
Forest stand	1.4 – 5.4	25.1	17.86	20
W. avege	1.8 - 7.4	24.93	20,14	20
		26.65	21.05	
Birch,				
Betula pendula				
Betula pubescens	1.2 – 4.6	23,81	8,93	18
W. avege	1.6 – 4.8	25,81	10,10	17
		24.81	9.23	
Shrubs, rhizomes				
Calluna vulgaris				
Ledum palustre	2.2 – 5.5	41.41	8,51	9
Vaccinium myrtillus	2.5 – 6.8	28,04	5,35	9
Vaccinium uliginosum	1.7 – 3.2	36.05	6,11	10
W.avege	2.1 – 6.5	24,96	5,17	12
		32.13	6.2	

W. avege, weigthed average based on number of samples.

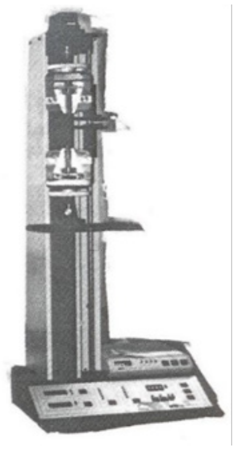

Figure 3 Hounsfield 5000 tensile tester and extensometer to the right and on top the 5 000 N load cell.

It is interesting to note that soil fertility will influence the strength properties of the roots and the tough rhizomes that are actually stronger than tree roots and thus rather important for the strength of the forest soil. Small roots are more elastic than coarser roots maybe because of less lignification. Thus, on fertile sites root damages may be more common, on the other hand the repair ability may be better.

Strength of tree root bark

The strength of root bark (for Picea abies, Norway spruce, and Pinus sylvestris, Scots pine) have been studied by Wästerlund.[10] Figure 4 shows the principal design of the test-rig to measure the strength of bark on the roots. By cutting in different ways the properties of bark could be measured (Figure 5) like tangential or longitudinal way or with total surrounded cutting the adhesion to wood samples could be measured and by doing that during different months the seasonal variation could be estimated.

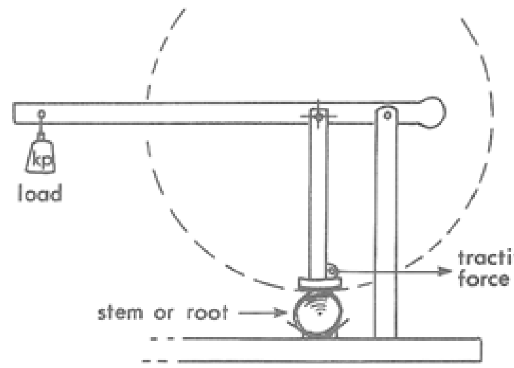

Figure 4 Principle drawing of test equipment for measuring the strength of bark.

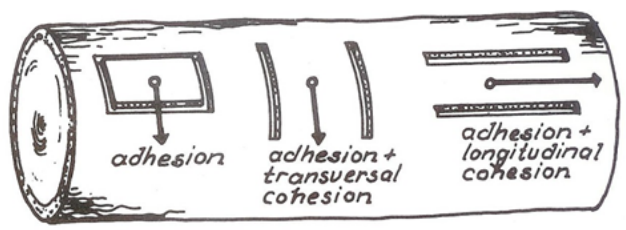

Figure 5 By cutting the bark of roots in these ways, adhesion to the wood or cohesion could be tested in the test equipment, and by sampling at different times its strength could be tested during different months.[10]

The sap period for these trees start in the top bud and continues down the stem and finally down to the root system, which in nortern Sweden is in July (based on several measurements on stem bark,[10,11] it is good that forestry in the Northern countries usually have their summer vacancy this period. Suppose a driven tire is passing a root. The root could be a spruce heart root lying almost uncovered on top of the soil. The wheel is entering the root and is resting only on the root with the wheel. The entry angle is 45° The contact area between the wheel and the root is 40 cm^2, (Figure 6). Suppose only the load of the tyre is influencing the root. The resultant of the force exposure affecting the root is equal to the load Q of the tire. The shear force F acting on the root bark is then F= Q cos 45°.

This may happen in September. To remove the bark, the shear forces must be more than 60 N cm^{-2}. The load should therefore not be heavier than 60x40/0.71=3.38 kN. The friction coefficient between the tire and the bark could be 0.6. This means that total loads above 5.63 kN will cause removal of the root bark. Suppose the tire has the dimension 500x22.5". With a supposed sinkage into the soil of 15%, this tire may have a total ground contact area of 50x56=2 800 cm^2. That tire should carry a load of less than 5.63 kN. The average ground pressure will be then be less than 5.63x10/2 800=20 kPa (10=bark adhesion).[9] Apparently, such low average ground pressures are hard to achieve with forestry machines and common types of tires. However, the example shows the importance of the load being distributed on a large contact area at the passage of single rootss.[12]

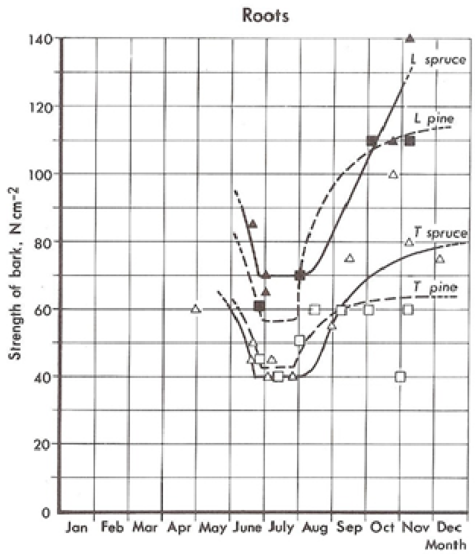

Figure 6 The seasonal variation of the strength of bark for roots (N per cm^{-2}). Spruce roots (Δ) tangential and (▲) longitudinal. Pine roots, (□) Tangential and (■) Longitudinal direction.[10]

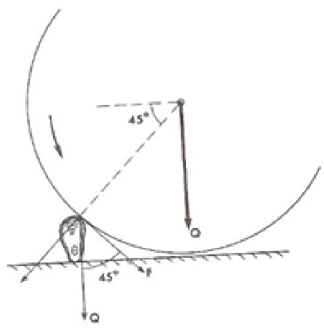

Figure 7 An example of the loading situation when a wheel is rolling over a superficial tree root.

Figure 8 Spruce roots with bark peel off after passage of forestry machines after a thinning operation.

Conclusion

No higher forces than: Load 25 kPa and traction less than 16 N to give the forest floor without a trace, which would be difficult to achieve. Rhizomes from shrubs are important for the strength of the forest floor. Soft rubber and less inflation pressure could be of benefit to reduce the sinkage into the ground and avoid stretching of the roots and rhizomes.

Acknowledgments

None

Conflicts of interest

The author declares there are no conflicts of interest.

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